Digital reconstruction of the Puck 3 wreck hull

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Abstract: The Puck 3 wreck is a 12th century clinker-built vessel, salvaged from the submerged remains of the medieval harbour in Puck, northern Poland, in 1990. Individual planks and other timbers were then passed on to the National Maritime Museum in Gdańsk for conservation. Following the procedures developed and used for the digital reconstruction of the other Puck harbour wreck, the longship P2, the timbers of the P3 cargo vessel were documented in 3D using the Faro Arm. This allowed for digital assembly of the individual timbers. On that basis a reconstruction of the complete hull was prepared and tested for hydrostatic properties.

Keywords: digital reconstruction, High Middle Ages, Slavic boat-building, lapstrake vessels

1. Introduction

The submerged medieval harbour in Puck, northern Poland (Fig. 1), has been studied since 1977, when it was discovered by a group of amateur divers. A logboat and four lapstrake vessels were found among the remains of complex harbour structure remains. Today, only two of them remain *in situ*, while the rest were salvaged. The logboat, dated to the 7th-8th centuries by ^{14}C analysis and designated as Puck 4; numbers assigned in order of discovery, was recovered in 1989. Since then it has been safely stored in the regional museum in Puck (Litwin 1995: 140). Both salvaged lapstrake vessels, Puck 2 and Puck 3, are part of the collection in the National Maritime Museum in Gdańsk (NMM). The one-of-a-kind 10th-century longship Puck 2 was recovered in 2005. Over the past several years it has been conserved in PEG, digitally recorded, reconstructed and prepared for exhibition (see Pomian, Litwin 2009; Litwin 2021; Litwinienko, Różycki 2021). Two Puck wrecks are still *in situ*. Puck 1, interpreted as a 14th century coastal trader, was uncovered and partially documented in 1983. However, years of lying in shallow, littoral waters contributed to its further degradation. In 2019, poorly preserved, scattered timbers were collected by the NMM's diving team and secured underwater with geotextile. The last wreck, Puck 5, was found during the Puck 3 salvage operation in 1990 (Szulta 2002). It was uncovered, partially documented and dendro-dated to the 13th century (Ważny 2001: 68). The wreck remains *in situ* and is currently being investigated and studied by NMM archaeologists.

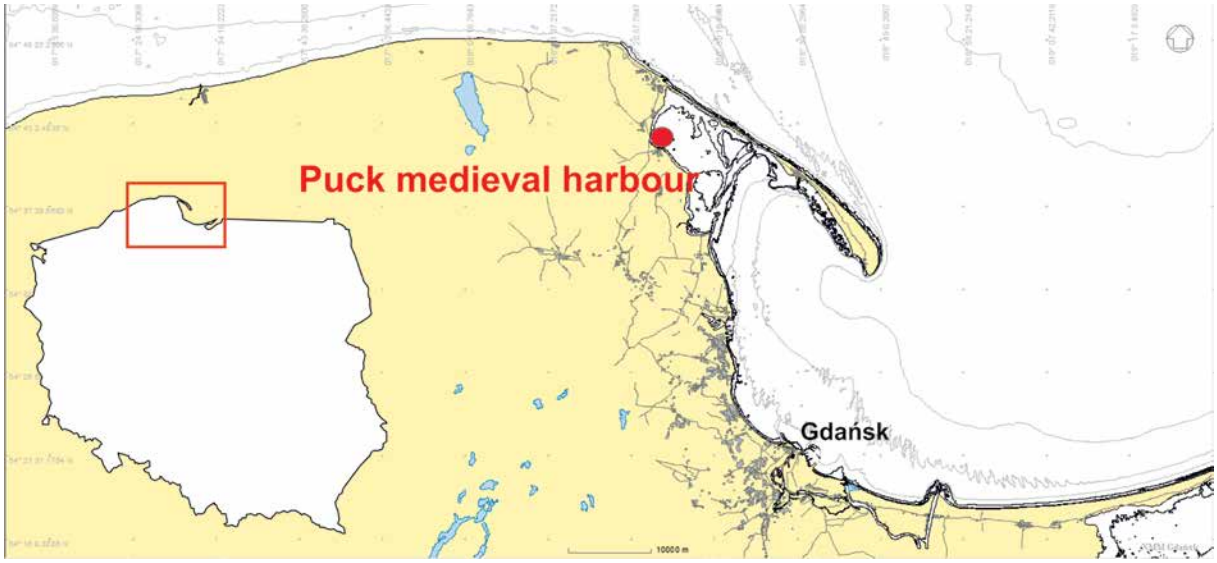

Fig. 1 Location of the Puck medieval harbour site (map: P. Litwinienko)

2. The Puck 3 wreck – discovery, salvage and conservation

The Puck 3 shipwreck was discovered in 1979 and its fore section was documented in 1983 during research conducted by W. Stępień (1984: 319). It was found in the western part of the site, 17 m south of the nearest recognisable harbour structure. The wreck, 11 m long and 3 m wide, lay in shallow waters, 1.5 m deep. It rested in an approximately W-E orientation, with its preserved bow facing west-north-west and submerged approx. 1.5 m into the seabed, while the midship was exposed, and thus prone to devastation. The wreck was covered with a layer of natural peat and no anthropogenic objects were observed within. In 1989, after a research hiatus lasting several years, it was decided to salvage the wreck, as it was observed that the exposed timbers were rapidly deteriorating (Szulta 2002: 77).

The wreck was fully examined and documented in 1990 by underwater archaeologists from Nicolaus Copernicus University in Toruń, while the NMM salvaged the wreck and assumed care of it for conservation, further study and future display. During the examination, apart from the actual wreck salvaged in several pieces, 86 loose structural elements were also extracted and passed on to the Museum (Szulta 2002: 77). Then the artefacts were documented (with drawings and photographs) and conserved with a PEG solution that was sprayed and brushed over the elements (Litwin 2021: 152). During the conservation process the wreck was studied to establish its chronology, identify the shipbuilding traditions employed during construction and define the best way to reconstruct it for exhibition purposes (Litwin 2000; Litwin 2021: 150).

Soon after its discovery, the wreck was carbon-dated to approximately AD 950 (Stępień 1984: 319). A total of fifteen dendro-samples were taken from the planking in subsequent years, which made it possible to set the wreck's chronology to the mid-12th century (after 1155). The dendro-provenance of the samples has still not been precisely defined – it most likely originated in the southern Baltic area, either in the vicinity of Gdańsk or Szczecin (Ważny 1999; Krąpiec, Ossowski 2003). The difference between the dating results may arise from the inadequate sampling of wood for radiocarbon dating or the bias in original interpretation (for an elaboration of inconsistencies between radiocarbon and dendrochronology results for dating clinker-built vessels see Ossowski, Krąpiec 1999).

3. The post-conservation digital documentation

In 2017, after documenting the Puck 2 longship (Litwinienko, Różycki 2021), the author, in cooperation with Janusz Różycki and Krzysztof Kurzyk from the NMM's Underwater Archaeology Department, began the digital recording of the conserved structural elements of the Puck 3 wreck, which was then being prepared for reconstruction in a specially designed cradle. Using the Faro ScanArm, a total of 95 artefacts were documented: keel, stem, five futtocks, 15 pieces of floor timbers, 11 knees, four thwarts (beams), two breast-hooks, two stem-planking connectors, 48 pieces of planking and six unidentified elements. 52 elements (mainly frames and floors) were laser scanned, while the rest (planking) was documented using a contact digitiser probe (see Jones 2015 for further reference). Next, the wireframe digital drawings were given surfaces and modelled into solid models used during the assembly of the digital model.

4. The wreck as found

Once documentation was completed, it became possible to assemble the individual elements in the digital model of the wreck in an attempt to recreate the as-found condition with the use of field data. The wreck is a clinker-built vessel built on a keel with almost half of the hull preserved, including the fore stem. The 8.39 m long keel has been almost entirely preserved; it is joined with a fore stem by a diagonal scarf fastened with a single large treenail. It is T-shaped in cross-section, which is 11 cm high and 17 cm wide at the widest part. Two rectangular (8 per 4 cm) grooves had been incised close to the scarf on the keel's upper surface, interpreted as being used to temporarily attach the garboard strakes to the keel and stem during the construction process using shipbuilding clamps (Litwin 2000: 263–264). This feature is present among several wrecks found in the Gulf of Gdańsk area, including Puck 2 and Orunia 3.

The fore stem is 2.3 m long and has some distinctive features in the form of extrusions for attaching the garboard strake, an oval hole in its lower part and a step for the second strake. The upper surface the stem has three rectangular grooves, such as those on the keel. A transition piece between the planking and the stem on both of the latter's sides was attached with nails in the form of a small plank formed by steps for the third and next planking strakes. The better-preserved port side transition piece is 1.6 m long and has steps for three strakes.

The planking has been preserved in good condition and to a considerable extent with up to six starboard and eight portside strakes. Most planking is still in large chunks of several planks are still connected to each other, with preserved moss luting. The moss species used was identified as *Dreponocladus aduncus*, which is common among early-medieval southern Baltic shipwrecks (Gos, Ossowski 2009). The planks, as well as other construction elements, are made of oak. They are approximately 2 cm thick and 20-25 cm wide. The longest complete (with both scarves) plank is 5.2 m long, while the shortest is only 1.7 m long. The strakes are clinker-laid with an overlap of 4 cm and joined with wedged wooden pegs 1.5 cm in diameter, placed every 10 cm. All strakes, except the sixth, are attached to the stem transition pieces; the sixth strake is shorter, as it terminates in a specially prepared step in the fifth strake, ca. 2 m from the stem. No traces of repair were identified on the planking.

The hull was reinforced with floor timbers, futtocks and knees. The floors, measuring approximately 7 cm sided and 10 cm moulded in section were fastened to the planking with treenails 3 cm in diameter and regularly placed every 1 m. Seven floors were preserved, including two V-shaped bow floor timbers. They covered six planking strakes on each side, being relatively flat in the midship. The lower surfaces of the floors had been shaped to fit with the lapstrake planking, with openings for the smooth flow of bilge water. Furthermore, five futtocks are preserved, extending the floors to the side in the vessel's midship; these were probably placed on floors no. 4, 5 and 7. The bow section was reinforced with two breast-hooks, connected to the planking with small pegs. Four rowing benches were preserved, including the one placed in the midship (2.9 m long) with an oval excision for the mast, as well as ten knees, reinforcing the sides above the benches.

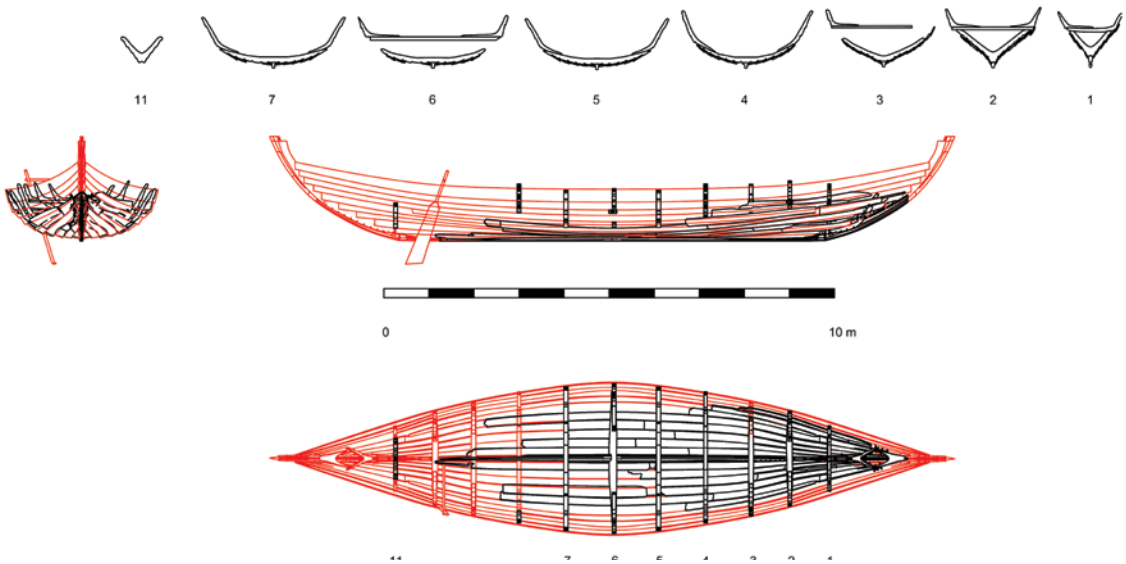

Fig. 2 Reconstruction drawing of the Puck 3 wreck, preserved timbers in black (drawing: P. Litwinienko)

5. Digital reconstruction of the hull

Digital reconstruction of the vessel's hull shape was done using Rhinoceros 5 software based on preserved elements, mainly the shape of the floor timbers and frames (Fig. 2). It was assumed that the ship was double-ended with a symmetrical bow and stern, which was common among medieval Southern Baltic vessels made in the Slavic shipbuilding tradition (see Litwin 2014: 31–22), and its widest floor was no. 6, with the bench and mast excision serving as the central frame. This central frame is situated 4.5 m from the preserved bow end of the keel, which after applying the assumed symmetry results in a 9 m total length for the keel (of which 8.4 m has been preserved). The preserved stem extends the hull 2.1 m forward (and, symmetrically, aft). After adding the reconstructed piece, shape of which was determined on the basis of the preserved curvature (approximate radius 3.6 m; see Litwin 2003: 262), this length increased to 3.1 m. The resulting overall hull length with stems is 15.2 m. The central rowing bench is 2.9 m long, and after adding its knees, the vessel's beam is 3.4 m. The bench does not rest on the floor timber itself, but rather on the reconstructed short frames that would make it higher and wider. The midship height of the ship is 1.1 m, while the stems rise 2.1 m above the keel. There would be ten planking strakes on each side. The total number of strakes is indicated by the height of the knees in the midship section. Nine planking strakes end on the stem and the sixth strake

ends on the fifth strake, which would increase the ship's beam. The overall reconstructed hull shape can be described as full; the ship is 1.6 m wide at the first frame, located at the stem.

The original hull shape was slightly distorted, most likely due to post-depositional processes that occurred while the shipwreck rested on the seabed covered by sediment. The bow section's V-shaped frames were apparently the sturdier pieces, as this part of the wreck is the least distorted, even though situated at the greatest depth. The distortion is most evident in the midship floor timbers, which had been flattened – floor no 7 was almost broken in half in the process. The keel is also slightly bent to the portside in its bow section, while its broken and eroded aft part, which lay above the sediment, juts upwards. It is unknown how and if the planking was distorted – after the conservation processes all planks are straight, their original and post-depositional curvature eliminated. In the digital reconstruction process, the distorted curvature of the midship floor timbers was altered to some degree to ensure the smoothness of planking which, as the hull was built shell-first, accounted for the original shape.

The ship is then a mid-sized (even though it is the largest of the early medieval Southern Baltic finds) transport vessel, 15.2 m long an 3.4 m wide, which gives it a beam to length (B:L) ratio of 1:4.47 (L:B 0.22). The vessel was most likely sail-propelled, as evidenced by the central beam. No mast step was found, however, as it was probably temporarily fastened to the floor timber. This type of mast step was found in several southern Baltic shipwrecks. The presence of frames and a simultaneous lack of benches on two floor timbers on both sides of the mast provided ample cargo space for transporting goods. The oars were probably used to manoeuvre during calm seas.

After modelling, the ship reconstruction was tested for hydrostatics in the Orca3D plug-in for Rhinoceros, using the methodology developed by Pat Tanner (Tanner 2020). Before calculations, it was necessary to prepare a simplified model of the hull, using the Orca Plate function, which enables the modelling of a hull's surface using control points placed alongside cross-sections. This surface was given weight, using the 'Orca Weight and Cost' properties tab: a model of each oaken construction element was given oak material density (800 kg/m3), hence the weight calculated by the software. The estimated lightweight displacement (empty hull with mast, with no provisions, ballast etc.) of the vessel is 1,554 kg. This empty hull sinks only 26 cm into the water, which is most probably the result of light planking, made of radially split oaken planks with a thickness of only 2 cm. This lightweight draft is similar to the result for Puck 2 (see Litwinienko, Różycki 2021, p. 311). As with the previously studied longship Puck 2, the medieval Icelandic Law (Tanner 2017: 173) was used to establish the minimum freeboard condition (F), according to the equation F=2D/5, which in this case equals 44 cm. The Puck 3 vessel fully loaded (achieving minimum freeboard) with ballast, provisions and a crew of 10 men (eight rowers, a helmsman and a lookout) displaces 8,934 kg of water and has a draft of 66 cm. The cargo capacity (including ballast, provisions and personal gear) of such a ship is 6,580 kg (approximately 6.5 t), while laden, with 50 cm of freeboard, the cargo capacity is 5,200 kg. The max heel angle, above which water pours into the open hull, is 15º in both loaded conditions, while the hull shows positive stability up to 25º of heel (Fig. 3). In order to achieve better sailing performance (higher freeboard and max. heel angle) the ship was probably loaded with even less cargo. The results of hydrostatic calculations are shown in Table 1.

Project	Lightweight	Loaded	Fully loaded
Length overall	15.2 m	15.2 m	15.2 m
Beam	3.4 m	3.4 m	3.4 m
Midship Depth	1.1 m	1.1 m	1.1 m
Waterline length/wet area	11 m/13.7 m^2	12.3 m/26.2 m^2	12.5 m/28.1 m^2
Displacement	1,554 kg	7,554 kg	8,934 kg
Draft	26 cm	60 cm	66 cm
Freeboard	84 cm	50 cm	44 cm
Crew number and weight	0	5 men = 800kg	5 men = 800 kg
Cargo, ballast, equipment, provisions, etc.	0	5,200 kg	6,580 kg
Max heel angle	35	15	15
LCB (measured from the bow)	7.62 m	8 m	7.85 m
VCB	17 cm	38.7 cm	42 cm
VCG	90 cm	64 cm	61 cm

Table 1 Results of Puck 3 hydrostatic simulations

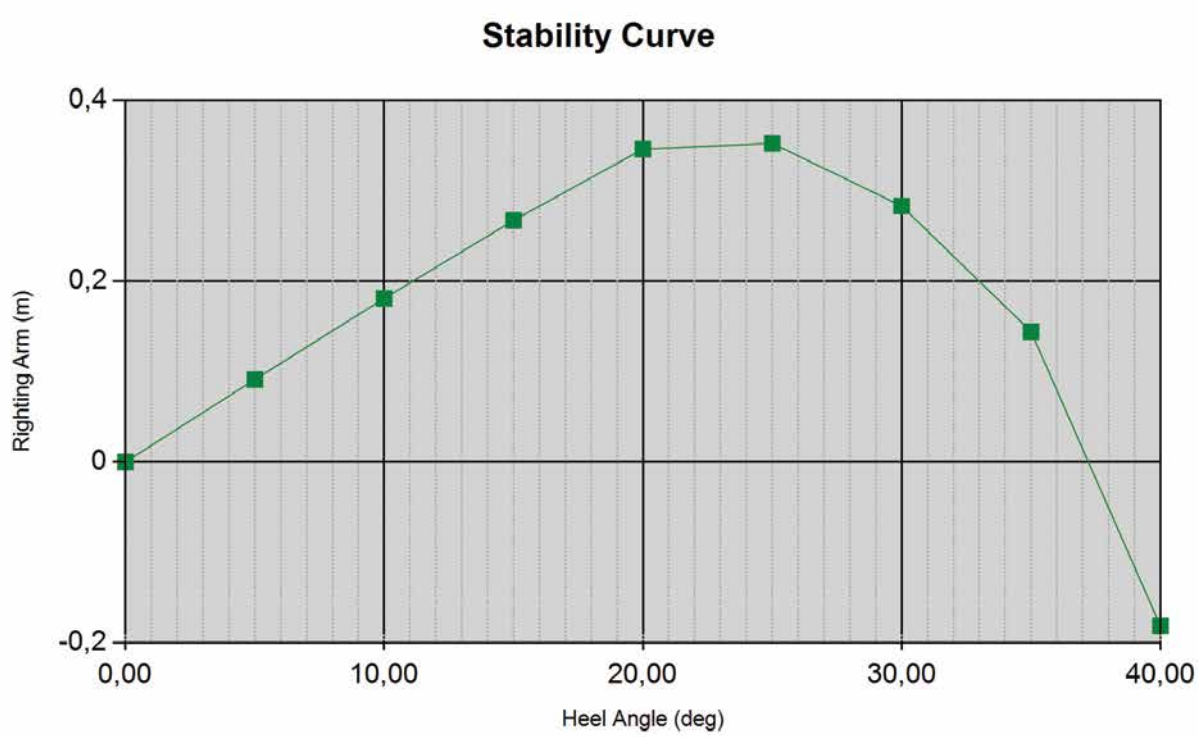

Fig. 3 The Puck 3 vessel stability curve in loaded state

6. Analogies and conclusions

The Puck 3 wreck seems to represent the typical southern Baltic (or Slavic) construction of a multi-purpose vessel that could be used for cargo transportation near the shoreline or for fishing. The wreck is very similar in its general proportions and construction features to at least four other wrecks dated to the 1150s–1200s and found adjacent to the Polish shoreline (Tab. 2).

Project	Puck 3	Czarnowsko 1	Charbrowo 1	Kamień Pomorski	Orunia 2
Dating	after 1155	after 1150s	after 1150s	after 1150s	after 1209
Length overall	15.2 m	13.76 m	13.2 m	12.1 m	11
Beam	3.4 m	3.35 m	3.3 m	2.7 m	2.27
Midship depth	1.1 m	0.85 m	1 m	1 m	0.87
Draft	66 cm	50 cm	-	65 cm	60 cm
B:L ratio	1:4.7	1:4.1	1:4	1:4.48	1:4.84
Cargo capacity	6.5 t (maximum)	5 t	6 t	5 t	3.5 t

Table 2 Shipwrecks dated to the latter half of the 12th century found adjacent to the Polish shoreline (data for wrecks other than Puck 3 after Filipowiak 2018: 97)

Of these four vessels, the Kamień Pomorski wreck, dated to the latter half of the 12th century, has recently been the subject of a published monograph that included its reconstruction (Filipowiak 2018). Both the Puck 3 and Kamień Pomorski ships are fairly similar, Puck 3 being proportionally longer and beamier (especially in the midship section), hence the greater cargo capacity of the former (Fig. 4). However, the stem from the Kamień Pomorski shipwreck has not been preserved, so it is probable that the vessel may have been longer. The Puck 3 wreck's shape is to some extent similar to the Skuldelev 3 shipwreck, interpreted as a Scandinavian local cargo-carrier used in safe and sheltered Danish waters. Its draft was calculated to 90 cm and cargo capacity to 4.5–5 t (Crumlin-Pedersen 2002: 195–243). The cross-sections of the bow and stern of both vessels are virtually identical; the greatest differences appear in midship, where the southern Baltic (Slavic) flat bottom of Puck 3 is clearly evident, as opposed to the prominent underwater

part of the Skuldelev 3 hull (Fig. 5). It seems that the Puck 3 vessel, the largest known southern Baltic wreck and the only one comparable to its Scandinavian counterparts, may have been used for local shipping in the sheltered waters of the Gulf of Gdańsk or, as there is a possibility of it originating from the Szczecin area, in the more turbulent open-sea areas of the Polish coastline.

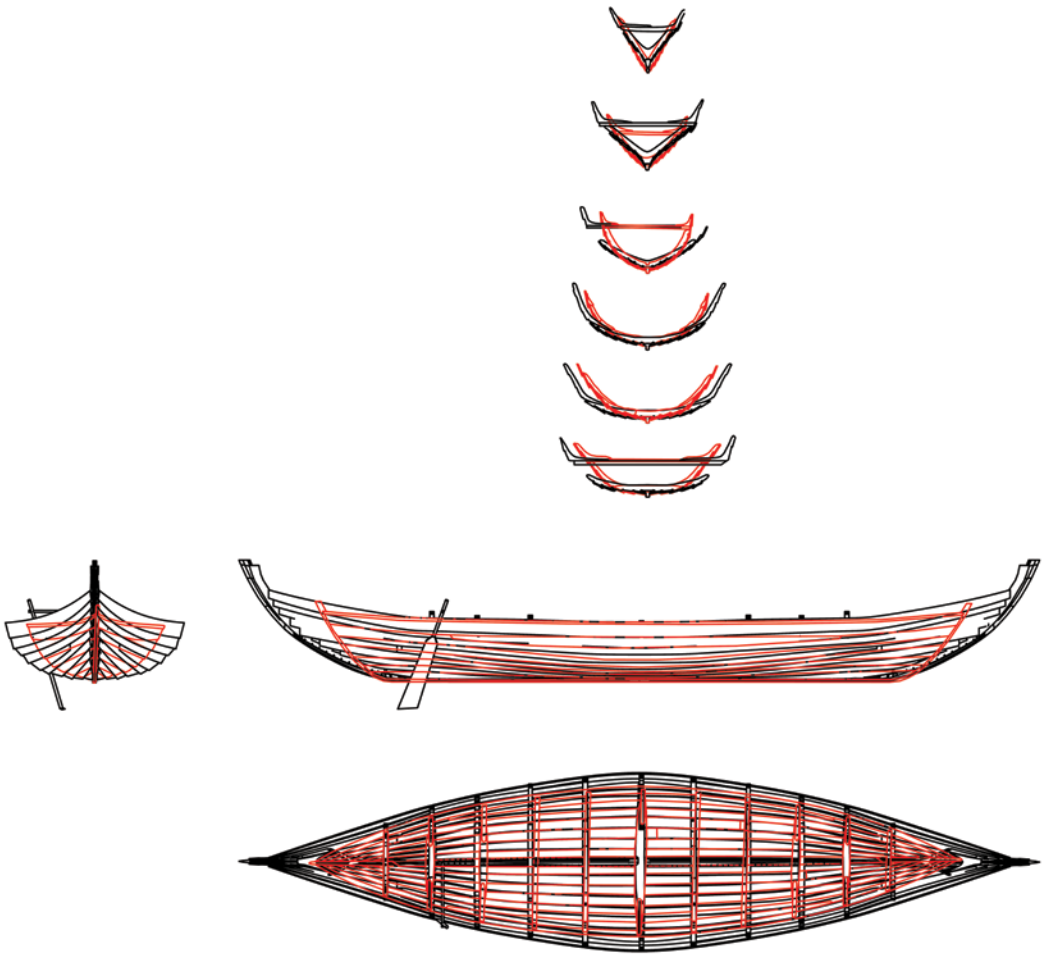

Fig. 4 Comparison of Puck 3 (in black) and Kamień Pomorski (in red) shipwrecks (Kamień Pomorski after Filipowiak 2018, digitised by P. Litwinienko)

The mid-12th century is considered the peak of Slavic maritime activity on the Baltic. This has been recorded in historical sources mentioning numerous raids by Slavic pirates against Danish and German towns and settlements, as well as the presence of Slavic traders in western Baltic ports (Ossowski 2016: 55). The historical sources mentioning maritime trade and warfare, written mostly by Danes and Germans, obviously focus on the western Slavs – the dukes of Pomerania and the Polabian pagans, leaving the Eastern Pomerania behind. Furthermore, the Baltic 12th century trade was dominated by Danish traders, with the main trade routes running from Lubeck and Schleswig east to Novgorod (Englert 2015: 21–23). However, the presence of several 12th century shipwrecks on the Polish coast, all of highly comparable form, cargo capacity and size not exceeding 15 m in length, may indicate the presence of a local trade route. These 12–15 m long multi-purpose vessels (Fig. 6) may reflect the scale of local exchange at a time of Danish dominance over long-distance Baltic trade, just a century before the rise of the Hanseatic League.

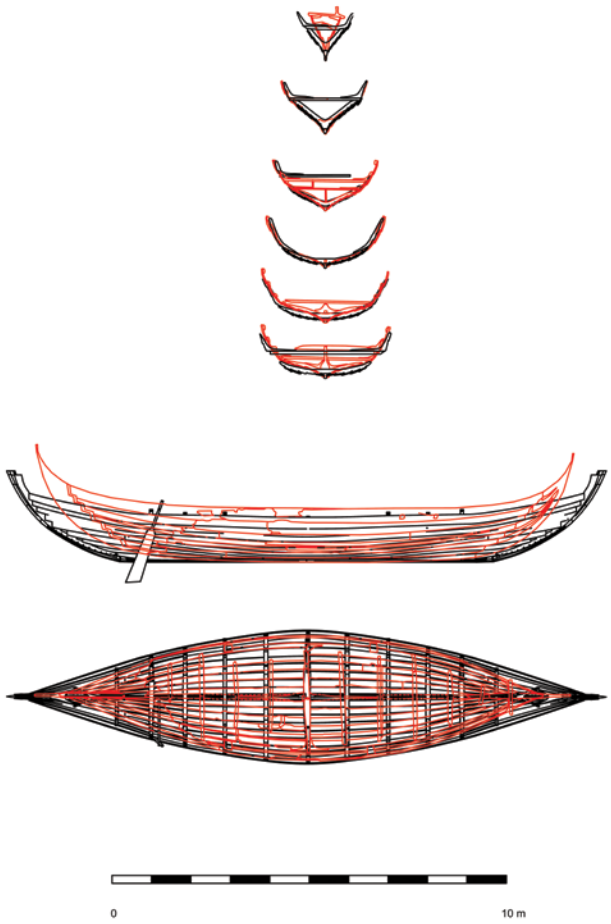

Fig. 5 Comparison of Puck 3 (in black) and Skuldelev 3 (in red) shipwrecks (Skuldelev 3 after Crumlin Pedersen 2002, digitised by P. Litwinienko)

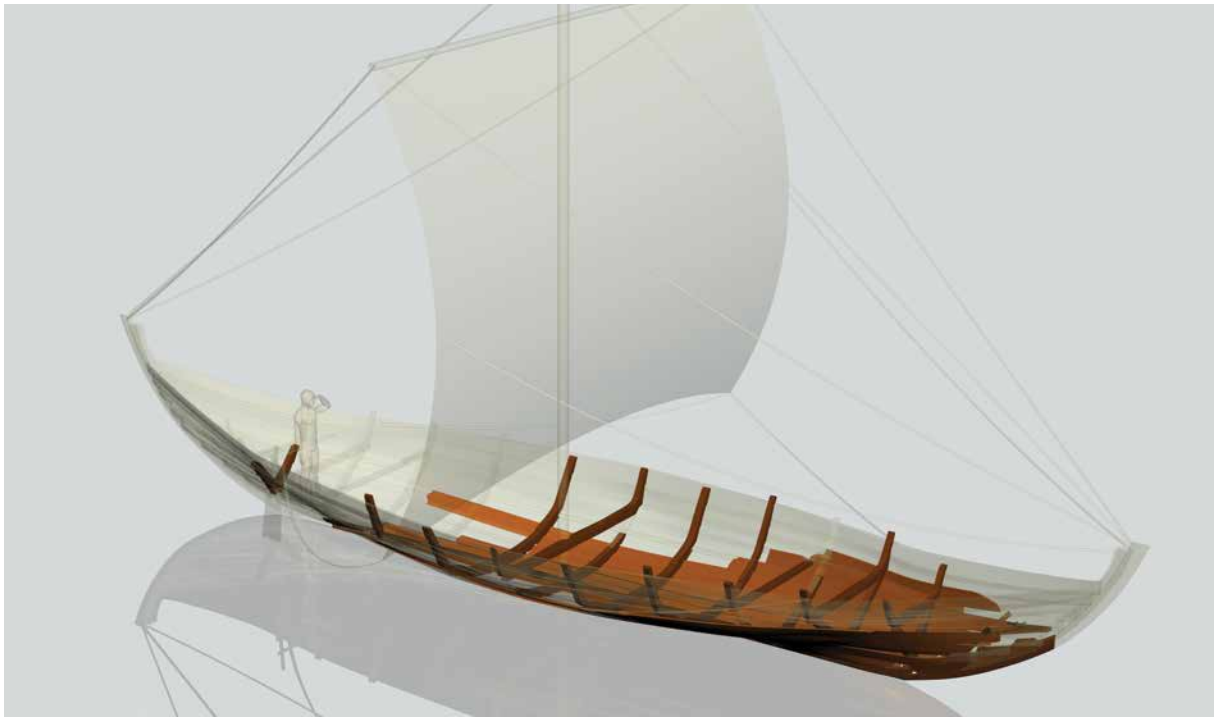

Fig. 6 Three-dimensional visualisation of the Puck 3 local trader (author: P. Litwinienko)

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